1. OPERATIONAL PROCEDURES

1.1 GENERAL

The Joint Typhoon Warning Center (JTWC) provides a variety of routine products and services to the organizations within its area of responsibility, including:

1.1.1 SIGNIFICANT TROPICAL WEATHER ADVISORIES — Issued daily, to describe all tropical disturbances and their potential for further development during the advisory period.

1.1.2 TROPICAL CYCLONE FORMATION ALERTS — Issued when synoptic or satellite data indicate the development of a tropical cyclone is likely within 24 hours in a specified area.

1.1.3 TROPICAL CYCLONE/ TROPICAL DEPRESSION WARNINGS — Issued periodically throughout each day to provide forecasts of position, intensity, and wind distribution for tropical cyclones in JTWC's area of responsibility (AOR).

1.1.4 PROGNOSTIC REASONING MESSAGES — Issued with each warning for tropical depressions, tropical storms, typhoons and super typhoons in the western North Pacific to discuss the rationale for JTWC's warnings.

1.1.5 PRODUCT CHANGES — The contents and availability of the above JTWC products are stipulated in USCINCPACINST 3140.1 (series). Changes to USCINCPACINST 3140.1T and JTWC products and services are proposed and discussed at the Annual Tropical Cyclone Conference. Significant changes this year to the warning system include: a new list of tropical cyclone names for the western North Pacific, Tropical Depression Warnings, inclusion of 30-kt wind radii at 48- and 72-hour forecast periods, and changing the message identifiers for the Prognostic Reasoning Messages and the Significant Tropical Weather Advisories.

1.2 DATA SOURCES

1.2.1 COMPUTER PRODUCTS — Numerical and statistical guidance are available from the USN Fleet Numerical Oceanography Center (FNOC) at Monterey, California. These products along with selected ones from the National Meteorological Center (NMC) are received through the Naval Environmental Data Network (NEDN), the Naval Environmental Satellite Network (NESN), and by microcomputer dial-up connections using military and commercial telephone lines. Numerical guidance is also received from Air Force Global Weather Center (AFGWC) at Omaha, Nebraska via the Pacific Digital Information Graphics System (PACDIGS), and from indigenous sources within our AOR.

1.2.2 CONVENTIONAL DATA — These data sets are comprised of land and shipboard surface observations, and enroute meteorological observations from commercial and military aircraft (AIREPS) recorded within six hours of synoptic times, and cloud-motion winds derived from satellite data . The conventional data is hand- and computer-plotted, and hand-analyzed in the tropics for the surface/gradient and 200 mb levels. These analyses are prepared twice daily from 0000Z and 1200Z synoptic data. Also, FNOC supplies JTWC with computer generated analyses and prognoses, from 0000Z and 1200Z synoptic data, at the surface, 850 mb, 700 mb, 500 mb, 400 mb, 200 mb levels, and deep layer mean winds.

1.2.3 SATELLITE RECONNAISSANCE — Meteorological satellite imagery recorded at USAF/USN ground sites and USN ships supply day and night coverage in JTWC's area of responsibility. Interpretation of these satellite data provides tropical cyclone positions and estimates of current and forecast intensities (Dvorak, 1984). A USAF tactical satellite site and Air Force Global Weather Central currently receive and analyze special sensor microwave/imager (SSM/I) data to provide estimates of 30-knot wind radii near tropical cyclones. Use of satellite reconnaissance is discussed further in section 2. Reconnaissance and Fixes.

1.2.4 RADAR RECONNAISSANCE — Land-based radar observations are used to position tropical cyclones. Once a well-defined tropical cyclone moves within the range of land-based radar sites, their reports are invaluable for determination of movement. Use of radar reports during 1989 is discussed in section 2. Reconnaissance and Fixes.

1.2.5 DRIFTING METEOROLOGICAL BUOYS — In 1989, no drifting meteorological buoys were specifically deployed in the western North Pacific for tropical cyclone warning support. Five of the nine buoys from the 1988 deployment and one from the 1987 deployment continued operations into 1989. Buoys provided data as Tropical Storm Winona (01W) and Typhoon Brenda (03W) crossed the Philippine Sea, but by late May the last buoy ceased operation. In 1989 Commander, Naval Oceanography Command put into action the NAVOCEANCOM Integrated Drifting Buoy Plan 1989-1994 to provide mini-drifter buoys to meet USCINCPACFLT requirements including tropical cyclone warning support.

JTWC acquires drifting buoy data directly through its Local User Terminal (LUT). The buoys transmit data to the TIROS-N polar orbiting satellites, which in turn relay the data to JTWC's LUT. Additionally, the data stored aboard the satellite are recovered via Service ARGOS and NOAA/NESDIS. NOAA/NESDIS processes and distributes the meteorological data to users via the National Meteorological Center (NMC) and the Automated Weather Network (AWN).

1.2.6 AUTOMATIC WEATHER OBSERVING STATIONS—Through a cooperative effort between Naval Oceanography Command and NOAA, the first of two HANDAR stations in the Mariana Islands was installed on Saipan in 1986. The second installation followed the next year on Rota. HANDAR data are received at JTWC through the Airfield Fixed Telecommunications Network (AFTN) and the AWN. Now, with the cooperation of NOAA, the Department of the Interior, and the Naval Oceanography Command, a network of 20 Automated Meteorological Observing Stations (AMOS) is planned to be completed throughout Micronesia by 1993. In 1988, the first AMOS site was installed at Faraulep Island (WMO 52005) in the central Carolines. In 1989, two more AMOS started operations at Ujae and Enewetak in the Marshall Islands. JTWC receives AMOS data from all sites via the AWN. In addition, data from the Faraulep site

Table 1-1. AUTOMATIC WEATHER OBSERVING STATIONS SUMMARY

Site	Location	Callsign	Type	System	Installed
Saipan	(15.2°N, 145.7°E)	15D151D2	HANDAR	ARC**	1986
Rota	(14.4°N, 145.2°E)	15D16448	HANDAR	ARC	1987
Faraulep	(8.6°N, 144.6°E)	FARP2/52005	AMOS	C-MAN/ARGOS*	1988
Ujae	(8.9°N, 165.8°E)	UJAP2	AMOS	C-MAN***	1989
Enewetak	(11.4°N, 162.3°E)	ENIP2	AMOS	C-MAN	1989

* System ARGOS data collection (via TIROS-N)
** Automated Remote Collection system (via GOES West)
*** Coastal-Marine Automated Network (via GOES West)

can be received real time via service ARGOS. Summary of current AMOS appears in Table 1.1.

1.3 COMMUNICATIONS

Primary communications support is provided by the Naval Telecommunications Center (NTCC), Nimitz Hill, a component of the Naval Communications Area Master Station, Western Pacific (NAVCAMS WESTPAC). JTWC uses the following communications systems:

1.3.1 AUTOMATED DIGITAL NETWORK (AUTODIN) — AUTODIN is used for dissemination of warnings, alerts and other related bulletins to DOD and other US Government installations. These messages are relayed for further transmission over Navy Fleet Broadcasts, and Coast Guard CW (continuous wave Morse Code) and voice broadcasts. AUTODIN messages can be relayed to commercial telecommunications for delivery to non-DOD users. Inbound message traffic for JTWC is received via AUTODIN addressed to NAVOCEANCOMCEN GQ//JTWC// or DET 1 1WW NIMITZ HILL GQ//CC//.

1.3.2 AUTOMATED WEATHER NETWORK (AWN) — The AWN provides weather data over the Pacific Meteorological Data System (PACMEDS). Operational at JTWC since April 1988, the PACMEDS allows Pacific-Theater agencies to receive weather information at 1200 baud. Early in 1989, JTWC also became the first Pacific unit to use the AWNCOM/WINDS software and a microcomputer to send and receive data via the PACMEDS. The system will eventually provide effective storage and manipulation of the large volume of meteorological reports available from throughout JTWC's vast AOR. Through the AWN, JTWC has limited access to data available on the Global Telecommunications System (GTS).

1.3.3 DEFENSE SWITCHED NETWORK (DSN) — DSN, formerly AUTOVON, is a world-wide general purpose switched telecommunications network for the Department of Defense. The network provides a rapid and vital voice link for JTWC to communicate tropical cyclone information to DOD installations. The DSN telephone numbers for JTWC are 344-4224 or 321-2345.

1.3.4 NAVAL ENVIRONMENTAL DATA NETWORK (NEDN) — The NEDN is the primary link to FNOC to obtain computer generated analyses and prognoses. It is also a backup communication line for requesting and receiving the objective tropical cyclone forecast aids from FNOC's mainframe computers. The NEDN allows JTWC to communicate directly to the other Naval Oceanography Command Centers around the world.

1.3.5 PUBLIC DATA NETWORK (PDN) — A commercial packet switching network that provides low-speed interactive transmission to users of FNOC products. The PDN is now the primary method for JTWC to request and receive FNOC produced objective tropical cyclone forecast aids. The PDN allows direct access of FNOC products via the Automated Tropical Cyclone Forecast (ATCF) system. The PDN also serves as an alternate method of obtaining FNOC analyses and forecast fields. TYMNET is the contractor providing PDN services to FNOC.

1.3.6 DEFENSE DATA NETWORK (DDN) —The DDN is a DOD computer communications network utilized to exchange data files. Because the DDN has links, or gateways, to non-military information networks, it is primarily used to exchange data with the research community.

1.3.7 TELEPHONE FACSIMILE (TELEFAX) — TELEFAX provides the capability to rapidly scan and transmit, or receive, documents over commercial telephone lines or DSN. TELEFAX is used to disseminate tropical cyclone advisories and warnings to key agencies on Guam and, in special situations, the other Micronesian Islands. Inbound documents for JTWC are received via commercial telephone at (671) 477-6186. If inbound through DSN, the Guam DSN operator 322-1110 can transfer the call to the commercial number 477-6186.

1.3.8 NAVAL ENVIRONMENTAL SATELLITE NETWORK (NESN) — The NESN's primary function is to pass satellite data from the satellite global data base at FNOC to regional centers. Similarly, it can pass satellite data from NOCC/JTWC to FNOC or other regional centers. Also, it provides a limited back-up for the NEDN.

1.3.9 AIRFIELD FIXED TELECOMMUNICATIONS NETWORK (AFTN) — AFTN was installed at JTWC in January 1990. Though AFTN is primarily for the exchange of aviation information; weather information and warnings are also distributed via this network. AFTN also provides point-to-point communication with other warning agencies. JTWC's AFTN identifier is PGUMYMYT.

1.3.10 LOCAL USER'S TERMINAL (LUT) — JTWC uses a LUT, provided by the Naval Oceanographic Office, as the primary means of receiving real-time data from drifting meteorological buoys and some of the Micronesia AMOS via the polar orbiting NOAA satellites.

1.4 DATA DISPLAYS

Equipment maintenance is provided by the Equipment Support Department of the Naval Oceanography Command Center, Guam.

1.4.1 NAVAL ENVIRONMENTAL DISPLAY STATION (NEDS) — The NEDS receives, processes, stores, displays and prints copies of FNOC environmental products. It drives the fleet facsimile broadcast and can also be used to generate the requests for objective tropical cyclone forecast techniques.

1.4.2 AUTOMATED TROPICAL CYCLONE FORECAST SYSTEM (ATCF) — The ATCF has decreased message preparation time and reduced the number of corrections to JTWC's alerts and warnings. In 1989 for the first time, the ATCF automatically computed the myriad of statistics calculated by JTWC. Links were established through a Local Area Network (LAN) to the NOCC Operations watch team to facilitate the generation of Tropical Cyclone Warning graphics for the Fleet Facsimile Broadcasts and their local metwatch and warning products for Micronesia. A module permits satellite reconnaissance fixes to be input from Det 1, 1WW into the LAN. Several other modules are still under development including: direct links to NTCC, the LUT, and AWNCOM.

1.4.3 PACIFIC DIGITAL INFORMATION GRAPHICS SYSTEM (PACDIGS) — The PACDIGS is a communications circuit that was expanded to include JTWC in 1988. Air Force Global Weather Central (AFGWC) at Omaha, Nebraska provides a standard set of numerical products to the PACDIGS circuit which can be used for additional evaluation in the development of tropical cyclone warnings.

1.4.4 NAVAL SATELLITE DISPLAY SYSTEM (NSDS) — The NSDS functions as a display of FNOC stored Defense Meteorological Satellite Program (DMSP) imagery and low resolution geostationary imagery . It is the primary means for JTWC to observe the Indian Ocean.

1.4.5 NAVAL SATELLITE DISPLAY SYSTEM-GEOSTATIONARY(NSDS-G) — The NSDS-G is the primary system used to process high resolution geostationary imagery for tropical cyclone positioning and intensity estimates for the western Pacific Ocean. Its built-in sectorizer allows monitoring of numerous cyclones or suspect areas on a small enough scale to expand and evaluate the data effectively.

1.5 ANALYSES

The JTWC Typhoon Duty Officer (TDO) routinely does manual streamline analyses of composite surface/gradient-level (3000 ft (914 m)) and Upper-tropospheric (centered on the 200 mb level) data for 0000Z and 1200Z each day. Manual sea-level pressure analyses concentrating on the mid-latitudes are available from the NOCC Operations watch team. Computer analyses of the surface, 850, 700, 500, 400, and 200 mb levels, deep layer mean winds, and frontal boundaries are available from the 0000Z and 1200Z FNOC data bases. Additional sectional charts at intermediate synoptic times and auxiliary charts, such as station-time plot diagrams and pressure-change charts, are analyzed during periods of significant tropical cyclone activity.

1.6 FORECAST PROCEDURES

1.6.1 INITIAL POSITIONING — The warning position is the best estimate of the center of the surface circulation at synoptic time. It is estimated from an analysis of all fix information received from one hour before to one and one-half hours after synoptic time. The analysis is aided by a computer-generated objective best track scheme that weights fix information based on its statistical accuracy. The TDO includes synoptic observations and other information to adjust the position, testing consistency with the past direction, speed of movement and the influence of the different scales of motions. If the fix data are not available due to reconnaissance platform malfunction or communication problems, or are considered unrepresentative, synoptic data and/or extrapolation from previous fixes are used.

1.6.2 TRACK FORECASTING — A preliminary forecast track is developed based on an evaluation of the rationale behind the previous warning and the guidance given by the most recent set of objective techniques (see 5.2), numerical prognoses, recent movement, satellite animation, and other objective and empirical techniques. This preliminary track is then subjectively modified based on the following considerations:

1.6.2.1 The prospects for recurvature or erratic movement are evaluated. This determination is based primarily on the present and forecast positions and amplitudes of the middle-tropospheric, mid-latitude troughs and ridges as depicted on the latest upper-air analyses and numerical forecasts.

1.6.2.2 Determination of the best steering level is partly influenced by the maturity and vertical extent of the tropical cyclone. Shallow or sheared systems would be steered by the lower-tropospheric flow, whereas deep or mature cyclones would be affected by mid-level or deep-layer steering. For mature tropical cyclones located south of the subtropical ridge axis, forecast changes in speed of movement are closely correlated with anticipated changes in the intensity or relative position of the ridge. When steering currents are relatively weak, the tendency for tropical cyclones to move northward due to internal forces are considered. North of the subtropical ridge the polar westerlies and shortwaves greatly affect tropical cyclone steering and intensity.

1.6.2.3 Over the 12- to 72-hour (12- to 48-hour in the Southern Hemisphere) forecast period, speed of movement during the early forecast period is usually biased towards persistence, while the later forecast periods are biased towards objective techniques. When a tropical cyclone moves poleward, and toward the mid-latitude steering currents, speed of movement becomes increasingly more biased toward a selective group of objective techniques capable of estimating acceleration.

1.6.2.4 The proximity of the tropical cyclone to other tropical cyclones is closely evaluated to determine if there is a possibility of interaction. If the proximity is less than 900 nm (1665 km), binary interaction tracking techniques are considered.

A final check is made against climatology to determine if the forecast track is reasonable. If the forecast deviates greatly from one of the climatological tracks, the forecast rationale is reevaluated.

1.6.3 INTENSITY FORECASTING — Heavy reliance is placed on the empirically derived Dvorak (1984) technique for forecasting tropical cyclone intensity. Other techniques used for forecasting intensity are extrapolation of synoptic wind and pressure data and climatology. An evaluation of the entire synoptic situation is made, including the location of major troughs and ridges, the position and intensity of the Tropical Upper-Tropospheric Trough (TUTT), if present. The vertical and horizontal extent of the tropical cyclone's cyclonic circulation, and the extent of the associated upper-level outflow patterns are considered. Animated satellite data plays a key role in the evaluation of intensification potential. Each intensity forecast is affected by the accompanying forecast track and environmental influences along that track; such as, terrain, vertical wind shear and extratropical weather features. JTWC also incorporates a new interactive climatology scheme to help determine intensity forecasts.

1.6.4 WIND-RADII FORECASTING — JTWC uses a wind profile and steering diagnostic developed by Major J. Martin and Dr. G. J. Holland (Office of Naval Research contractor). The technique adapts an earlier work (Holland, 1980) and specifically addresses the need for realistic 30-, 50- and 100-kt wind radii around tropical cyclones. It solves equations for basic gradient wind relations within the tropical cyclone area, using input parameters obtained from enhanced infrared satellite imagery. The diagnosis also addresses asymmetric areas of winds caused by tropical cyclone movement. Size and intensity parameters are used to diagnose internal steering components of tropical cyclone motion known collectively as "beta-drift".

1.6.5 EXTRATROPICAL TRANSITION — When a tropical cyclone is forecast to become an extratropical system, JTWC coordinates the transfer of warning responsibility with the appropriate Naval Oceanography Command Regional Center, which assumes warning responsibilities for the extratropical system.

1.6.6 TRANSFER OF WARNING RESPONSIBILITIES — JTWC coordinates the transfer of tropical warning responsibility for tropical cyclones entering or exiting its AOR. For tropical cyclones crossing the dateline in the North Pacific Ocean, JTWC coordinates with the Central Pacific Hurricane Center (CPHC), Honolulu via the Naval Western Oceanography Center (NWOC), Pearl Harbor. For the South Pacific Ocean, JTWC coordinates with NWOC.

In the event JTWC should become incapacitated, the Alternate Joint Typhoon Warning Center (AJTWC), co-located with NWOC, assumes JTWC's functions.

1.7 WARNINGS

JTWC issues two types of warnings: Tropical Cyclone Warnings and Tropical Depression Warnings.

Tropical Cyclone Warnings are issued when a closed circulation is evident and maximum sustained winds are forecast to reach 34 kt (18 m/sec) within 48 hours, or when the tropical cyclone is in such a position that life or property may be endangered within 72 hours.

Each Tropical Cyclone Warning is numbered sequentially and includes the following information: the current position of the surface center; estimate of the position accuracy and the supporting reconnaissance (fix) platforms; the direction and speed of movement during the past six hours (past 12 hours in the Southern Hemisphere); and the intensity and radial extent of over 30-, 50-, and 100-kt surface winds, when applicable. At forecast intervals of 12, 24, 48, and 72 hours (12, 24, and 48 hours in the Southern Hemisphere), information on the tropical cyclone's anticipated position, intensity and wind radii is provided. In addition, vectors indicating the mean direction and mean speed between forecast positions are included in all warnings.

Warnings in the western North Pacific and North Indian Oceans are issued every six hours valid at standard times: 0000Z, 0600Z, 1200Z and 1800Z (every 12 hours: 0000Z, 1200Z or 0600Z, 1800Z in the Southern Hemisphere). All warnings are released to the communications network no earlier than synoptic time and no later than synoptic time plus two and one-half hours, so that recipients are assured of having all warnings in hand by synoptic time plus three hours (0300Z, 0900Z, 1500Z and 2100Z).

Tropical Depression Warnings are issued only for western North Pacific tropical depressions that are not expected to reach the criteria for Tropical Cyclone Warnings, as mentioned above. The depression warning contains the same information as a Tropical Cyclone Warning except the Tropical Depression Warning is issued every 12 hours at standard synoptic times and extends only to the 36-hour forecast period.

Both Tropical Cyclone and Tropical Depression Warning forecast positions are later verified against the corresponding best track positions (obtained during detailed post-storm analyses) to determine the most probable path and intensity of the cyclone. A summary of the verification results for 1989 is presented in section 5. Summary of Forecast Verification.

1.8 PROGNOSTIC REASONING MESSAGES

These plain language messages provide meteorologists with the rationale for the forecasts for tropical cyclones in the western North Pacific Ocean. It also discusses alternate forecast scenarios. Prognostic reasoning messages are prepared to complement each warning. In addition to this message, prognostic reasoning information is provided in the remarks section of warnings when significant forecast changes are made or when deemed appropriate by the TDO.

1.9 TROPICAL CYCLONE FORMATION ALERTS

Tropical Cyclone Formation Alerts are issued whenever interpretation of satellite imagery and other meteorological data indicates that the formation of a significant tropical cyclone is likely. These alerts will specify a valid period not to exceed 24 hours and must either be canceled, reissued, or superseded by a warning prior to expiration.

1.10 SIGNIFICANT TROPICAL WEATHER ADVISORIES

This product contains a description of all tropical disturbances in JTWC's area of responsibility (AOR) and their potential for further (tropical cyclone) development. In addition, all tropical cyclones in warning status are briefly discussed.

Two separate messages are issued daily and each is valid for a 24-hour period. The Significant Tropical Weather Advisory for the Western Pacific Ocean (ABPW10 PGTW) covers the area east of 100° east longitude to the dateline and is issued by 0600Z. The Significant Tropical Weather Advisory for the Indian Ocean (ABIO10 PGTW) covers the area west of 100° east longitude to the coast of Africa and is issued by 1800Z. These are reissued whenever the situation warrants. For each suspect area, the words "poor", "fair", or "good" are used to describe the potential for development. "Poor" will be used to describe a tropical disturbance in which the meteorological conditions are currently unfavorable for development. "Fair" will be used to describe a tropical disturbance in which the meteorological conditions are favorable for development, but significant development has not commenced.

"Good" will be used to describe the potential for development of a disturbance covered by an alert.